AAS 95-041

AMERICAN ASTRONAUTICAL SOCIETY

THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS SPACECRAFT GUIDANCE, NAVIGATION AND CONTROL INTERFACE STANDARDS INITIATIVE: PROGRESS “1’() DATE

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18th ANNUAL AAS GUIDANCE AND CONTROL CONFERENCE

February 1-5, 1995
Keystone, Colorado

Sponsored by
ROCKY MOUNTAIN SECTION
AMERICAN ASTRONAUTICAL SOCIETY

AAS Publications Office, P.O. Box 28130- San Diego, California 92198

THE AMERICAN INSTITUTE OF AERONAUTICS ANI) ASTRONAUTICS SPACECRAFT GUIDANCE, NAVIGATION ANI) CONTROL INTERFACE STANDARDS INITIATIVE: PROGRESS TO DATE

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with Frederic Agardy[2], John Allen[3], Frank Bauer[4], Tom Bauer[5], Jeff Bone[6], Doug Caldwell[7], John Casserino[8], Dorian Challoner[9], Jerry Clingan[10], Ray Crum[11], Tom Darone[12], Len Dorsky[13], Richard Dynes[14], Richard Flanagan[15], Paul Graves[16], Joel Gambino[17], Donald Krueger[18], Robert Meya[19], David Pruett[20], Wade Radford[21], Otilia Rodriguez-Alvarez[22] and David Ward[23]

The American Institute of Aeronautics and Astronautics (AI AA) has undertaken an important new standards initiative in the area of spacecraft Guidance, Navigation and Control (GN&C) subsystem interfaces. The central objective of this effort is to establish standards that will promote interchangeability of major GN&C components, thus enabling substantially lower spacecraft development costs. The standardization targets are specifically limited to interfaces only, including information (i. e., data and signal), power, mechanical, thermal and environmental interfaces between various GN&C components and between GN&C subsystems and other subsystems. The current emphasis is on information interfaces between various hardware elements (e.g., between star trackers and flight computers). The poster presentation will briefly describe the program, including the mechanics and schedule, and will publicize the technical products as they exist at the time of the conference.

1NTROI)1JC'J'1ON

During the formative days of the spacecraft industry, engineers bad to **invent the** practice of spacecraft development, including" the. decomposition of spacecraft into major subsystems (like attitude control, power and telecommunication), the development of basic components (like star trackers and inertial reference units), and the development of interfaces to make all the constituent elements operate together. Today, there is fair agreement within the community as to what the major subsystems of a spacecraft are, and there. are vendors who offer product line.s in the component areas. But for

1,7, 13 Jet Propulsion Lab., 2 Aerospace Corp., 3 Daedalian Systems Corp., 4,17,18,22,23 Goddard Space Flight Center, 5 Microcosm, 6 Lockheed Missiles and Space Co., 8 Air Force Phillips Lab., 9 Hughes Space and Comm. Co., 10,15 Boeing, 11,19 Honeywell Satellite Systems, 12 Space Applications Corp., 14 Aero Astro, 16 Martin Marietta Astro Space, 20 Johnson Space Center, 21 Applied Physics Lab.

various reasons (e.g., vested interests, personal prejudices, no accepted standards), engineers are all still largely wrestling with the interfaces repeatedly for each new spacecraft. Up until now, the Spat.ecraf{ industry has been able to follow this practice and largely get away with it. 1 lowever, as everyone knows, times have changed (see, e.g.. Ref. I).

The space race (along with (he ICBM program) was undertaken in the 50's and 60's for national security reasons and for international prestige. At that time, the p ublic and the congress, were supportive of space expenditures, because they were fearful of the Soviet Union, and they were unwilling to accept being anything less than best after wining the world war in the 40's and after the rapid growth and tremendous prosperity of the 50's. Also, it was new and exciting. It captured the public's imagination. The possibilities for commercial exploitation, first in telecommunication, and later in Earth resources management were clear and seductive. After the extraordinary success of the Apollo program, however, the public's enthusiasm began to Wane. Now, with the break up of the Soviet Union and the end of the cold war, the loss of interest is more or less complete. The traditional selling points no longer sell. Couple this with today's deep recession and government down-sizing, and the result is major problems for the spacecraft industry. The commercial sector is hit as hard as defense and space science. because of fierce competition from alternatives to space technology, like fiber optics and airborne or balloon borne platforms.

Today, the livelihoods of aerospace professionals arc at risk, and it is time to get serious about process improvement and cost containment. It has been demonstrated many times in many other high technology industries that one of the most effective ways to control costs and to stimulate vitality is to use standard interfaces wherever possible (see, Exhibits 1 and 2, and Ref. 2).

There is no reason, in principle, why sometime in the near future, a spacecraft designer could not call a vendor, order, for example, a star tracker that meets his or her performance requirements and complies with published interface standards, take delivery, plug it into their GN&C subsystem, and find that it works the first time it is powered up. This has, after all, been achieved in other industries whose components are just as complex as those found in spacecraft. Consider the microcomputer industry for example.. It is now possible to buy a printer off the shelf, take delivery, take it out of the box, plug it into the wail and a microcomputer, and print professional looking documents in minutes. Ail that is required to get to this point in the aerospace industry is cooperation.

To address this important need, The American Institute of Aeronautics and Astronautics (AI AA) has undertaken a new standards initiative in the area of spacecraft Guidance, Navigation and Control (GN&C) subsystem interfaces. The goal of this undertaking is to dramatically reduce spacecraft development cost by standardizing interfaces between GN&C subsystem components (e. g., actuators, sensors, and computer) and software (e. g., flight computer, operating system and applications modules), and between GN&C subsystems and other subsystems (e. g., command and data subsystem, power subsystem and ground operations resources). Adoption of particular hardware solutions, as was attempted in tbc NASA Standard Component program of the 70's, is specifically not part of the objective. Moreover, a special effort is being made to formulate the standards in such a way that they do not constrain technology development. The overall scope of the program encompasses information (i.e., data and signal), power, mechanical, thermal and environmental interfaces.

The success of the effort will be measured by the extent to which, within the next three to five years, spacecraft GN&C subsystem designers can choose plug and play compatible hardware and Software from a variety of vendors, expend little or no effort specifying the interfaces having confidence that all the interfaces will be compatible, and integrate and test the subsystem quickly and easily. At the same time, success will mean the introduction of new products, reflecting innovation, and offered at lower cost.

Support for the initiative is widespread (see Exhibit 3), with active participation from industry (Hughes, Lockheed, Boeing, Martin Marietta, Honeywell, Microcosm, Acro Astro, Ithaco), NASA (GSFC, JPL, JSC) and the DoD (ARPA, APL, Aerospace Corp., Air Force). Responsibility for the coordination of tbc activity lies with AIAA's GN&C Committee on Standards (CoS).

The initiative is being carried out according the general procedures outlined in Ref. 3. These procedures are approved by the American National Standards Institute (ANSI), and indeed it is expected that the documents produced through the program will receive ANSI endorsement. Endorsement by the International Standards Organization (1S0) will be pursued concurrently.

The committee's approach includes coordinating{' closely with related activities being carried out by the Institute of Electrical and Electronics Engineers (IEEE), the Society of Automotive Engineers (SAE), the Consultative Committee on Space Data Systems (CCSDS), the Strategic Avionics Technology Working Group (SATWG) and other groups concerned with space system standards. The committee focuses on the unique requirements of spacecraft GN&C components (e.g., star trackers and reaction wheels), exploiting the products of other organizations where appropriate. The committee's current emphasis is on information interfaces between hardware elements.

SCHEDULE

A program schedule covering the first four years of what is expected to evolve into an ongoing effort is shown in Exhibit 4. The schedule reflects the goal of publication of one or more AIAA standards publications (i.e., Guide, Recommended Practice or Standard documents) on roughly two year centers. Standards will be reviewed, and if appropriate revised, within five years of publication in accordance with AIAA procedures (Ref. 3). The schedule includes a period Of candidate standards testing at user facilities for each new document.

FUNDING

The standards committee is comprised of volunteers from a broad cross section of directly and materially affected interest groups, including commercial GN&C system developers, NASA, DoD and GN&C component suppliers. The submission of standards for evaluation, as well as the provision of test facilities and personnel, is also voluntary. AIAA provides clerical and administrative support, and support for publications, meetings and promotion.

PROGRESS TO DATE

The committee has had five meetings (as of the date of the 1995 Keystone Conference) since the initiative was launched in August of 1993, one of which was a public meeting conducted as a workshop (see Exhibit 4). It was decided at the first meeting (Ref. 4) that the committee should limit its initial scope, as a pathfinder, to information interfaces between major hardware elements (see Exhibit 5). Scope expansions, to include more of the total interface problem (e.g., electrical and mechanical interfaces, etc.), will occur as experience is gained and as appropriate experts are added to the committee. These expansions will be taken up by dedicated subcommittees formed for the purpose. The following is a brief summary of the information interface standard in its current form.

The basic architecture of the avionics shall be open, allowing the possible combination of multiple interface types from a variety of suppliers in order to accommodate optimized solutions for particular applications (Ref. 5). The general framework is depicted in Exhibit 6.

The architecture allows a parallel back plane to support, for example, high speed direct transfers between processors and memory or peripheral devices The parallel back plane will itself be one of a few (perhaps just one) recommended industry standards. Futurebus+, which is currently being defined by the IEEE and which will specifically include a space profile (Refs. 6-8), is being considered as the one recommended standard.

The architecture also allows a serial cable bus, a local area network (LAN) and point-to-point interconnections, including point-to-point serial digital links and both analog and hi-level discrete links. The standard specifies that all GN&C peripheral devices (i.e., sensors and actuators) communicate with the processor that hosts the GN&C application software through the serial cable bus. Moreover, the standard specifics that all the information traffic to and from each peripheral device, including health and status data, be multiplexed and transferred over the serial cable bus. The SAE's fiber optic AS-1 773 (Ref. 9), which is a dual rate (i.e., 1 and 20 Mbps) outgrowth of the Department of Defense's fiber optic MIL-STD-1773 (Ref. 10), is being strongly favored for specification as the serial cable bus for this standard. Note that although the architecture allows point-to-point interconnections, these are discouraged, and the standard provides no specific guidance on their implementation.

The LAN allows multiple subsystems on physically large spacecraft to conveniently exchange information. The question of which particular LAN or LAN's to specify for GN&C applications has not yet been considered.

Notice that the architecture automatically allows a GN&C subsystem to be accessed through a wide area network (WAN) that may encompass multiple spacecraft and ground terminals (e. g., as in the Iridium or Teledesic systems [Refs. 11, 12]). That is, the GN&C subsystem could interface with a spacecraft telecommunication subsystem that includes a WAN terminal through either the LAN, the serial cable bus, or a discrete link, though again the latter is discouraged.

A survey of typical GN&C peripheral devices (see, e.g., Exhibit 7) revealed that some, like star trackers, are generally sophisticated enough to accommodate a serial cable bus interface with minimal impact on their cost, mass, volume or power requirements. Indeed, some manufacturers of such components already offer them with MIL-STD-1553 interfaces, whose protocol is identical to that of AS-1773. On the other hand, others, like sun sensors, arc intrinsically of such simplicity that the introduction of a serial cable bus interface represents a substantial ncw addition. Therefore, full compliance with the standard is expected to take longer for some types of devices than others. However, considering the cost impact of the serial cable bus decision at the overall system level, the proposed standard is clearly beneficial, because the system level savings far outweigh the anticipated cost increase of peripherals.

For each specific type of GN&C peripheral device, the standard provides a definition of the information content, formal, timing, and, where applicable, the order. It also provides a definition of the device level protocol (as opposed to the bus protocol), and the command, measurement, parameter and status dictionaries for each device type. A partial list of the devices covered to date is shown in Exhibit 8. For brevity, the definitions (see, e.g., Exhibit 9) arc not included in this poster summary. However, they will be publicized at the conference, as they appear at that time, within a preliminary draft of the complete standard. Working definitions are given in Refs. 13 and 14.

A generic representation of the flow of information in a GN&C system is shown in Exhibit 10. Under the proposed standard, the manufacturer of a GN&C sensor or actuator will be free to choose the level at which to define the information interface to their device based on the market they arc targeting and the expected profitability of that level for their particular product. This makes it possible for new types of devices, with either higher or lower level data products or capabilities to be introduced al a later time within the general framework of the interface standard. However, the standard defines the interface at onc particular recommended level reflecting the current state of the art and a reasonable projection of near term future developments. As per AIAA guidelines, the standard will reviewed and updated at least once every five years in order to keep pace with technology and market trends.

System developers faced with the task of integrating noncompliant peripheral devices will be advised to accomplish this though an adapter that is itself compliant with the standard. Third party vendors will be encouraged to offer such adapters for popular non-compliant peripherals. Moreover, the AIAA GN&C CoS is prepared to commission the development of Recommended Practice documents (Ref. 3), to define low level interface recommendations (e. g., voltages, impedances, connectors, etc.) for such components.

TIMING

Accurate timing and synchronization of Critics] GN&C functions will be ensured by broadcasting a timing announcement followed by a timing mark over the AS-1773 bus. 1(is envisioned that the central processing element, which will bc the nominal bus master, will have access to a sufficiently accurate reference clock for this purpose. Timing and synchronization accuracy's of better than 1 μ scc arc expected to be achievable. through this method.

FUTURE WORK

Future work will focus, in part, on finalizing the definitions of the input and output information content, format, timing, and order for each of the GN&C peripheral devices identified as principal components, and on defining the device level protocol and the command, measurement, parameter and status dictionaries for each of those device types. As reported above, this work has already started for many of the important GN&C peripherals. Indeed, in some cases, work has begun on devices not currently marketed commercially (e.g., magnetic torquer system). Work on the important topic of cabling and connectors is just getting started. As shown in Exhibit 4, the committee plans to be ready for public balloting on the information interface standard by July 1, 1995, and plans to release that document by January 1, 1996.

SUMMARY

An overview of AIAA's GN&C interface standard initiative. has been presented, and the current status of the effort has been described, Publication of the first recommended standard, which will cover information interfaces between major hardware elements is scheduled for January 1, 1996. As with all voluntary standards, this one will be the product of a broad cross section of materially effected parties, and will represent substantial agreement within the community it serves. This paper is presented in a continuing effort to keep the public informed about the activities of the GN&C standards committee, and to invite active participation in the development of its products.

Expansions of the committee's scope only await the emergence of interested volunteers. The possibility of interface standards for GN&C software (e. g., between GN&C applications and each other, between GN&C applications and the host computer operating system, between GN&C applications and hardware drivers, and be. tween hardware drivers and hardware) appears of be virgin yet particularly fertile ground. With the advent of automatic code generators, the time for such standards seems right. Other important areas awaiting volunteers to address them arc the mechanical, electrical, thermal and environmental interfaces of GN&C components, and the interface between the spacecraft GN&C system and ground resources, Interested individuals are urged to contact the authors.

ACKNOWLEDGMENTS

The work described in this paper was carried out under direct voluntary support from the following organ izations: NASA, California institute of Technology Jet Propulsion Lab., Aerospace Corp., Daedalian Systems Corp., Goddard Space Flight Center, Microcosm, Lockheed Missiles and Space Co., Air Force Phillips Lab., Hughes Space and Comm. Co., Boeing, Honeywell Satellite Systems, Space Applications Corp., Aero Astro, Martin Marietta Astro Space, Advanced Research Projects Agency, Naval Research Lab., Johnson Space Center, Ithaco. The AIAA provided direct support for meetings and communication. The authors would like to thank tbc management of their home organizations for their personal support and encouragement, and Mr. J. French of the AIAA for his valuable guidance. The authors would also like to express their gratitude to the American Astronautical Society (AA S), and in particular to the organizers of the AAS Guidance and Control Conference, for making the forum of the con ference available.

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Exhibit 1. Benefits of Interface Standardization

To hardware and software component suppliers:

- Lower design cost - through re-use of designs
- Lower development costs - by exploiting a broader experience base
- Expanded market opportunities - multiple customers for given products
- Greater opportunity for and emphasis on innovation commoditized interfaces
- Expanded market volume - more projects

To spacecraft developers and spacecraft development customers:

- Lower design and development costs - less time specifying interfaces
- Lower manufacturing costs - less time integrating and debugging
- lower recurring costs - through lower component costs
- More reliable components - more experienced suppliers
- More capable components - through increase supplier emphasis on innovation
- More capable systems - by applying money saved to additional system capability .

To the aerospace industry:

- Greater number of projects - due to lower project costs
- Shorter development times - more opportunities to use off-the-shelf components
- Increased pace of innovation - becomes critical element of competition
- New business opportunities - for example, technical application software, bundled components (i.e., new levels of integration), interface components and devices.

Exhibit 2. Potential Cost Savings From Interface Standardization

Areas of potential savings:

Time spent specifying interfaces and interpreting interface specifications

Time spent designing and developing custom interfaces

Time spent integrating and debugging systems

Assessment of potential savings:

Brief conservative analysis of one representative spacecraft indicates that at least 10% of the attitude control system budget is a potentially avoidable cost associated with custom interfaces.

Result appears to apply to spacecraft overall.

If applied to the entire NASA budget, this could amount to over $1B per year.

Exhibit 3. Organizations Represented on Committee

Advanced Research Projects Agency
Acro Astro
Aerospace Corporation
Air Force Phillips Laboratory
Applied Physics Laboratory
Boeing
Goddard Space Flight Center
Honeywell Space Systems
Hughes Space and Communications
Institute of Electrical and Electronics Engineers
Ithaco
Jet Propulsion Laboratory
Johnson Space Center
Lockheed Missiles and Space Company
Martin Marietta
Microcosm
Society of Automotive Engineers

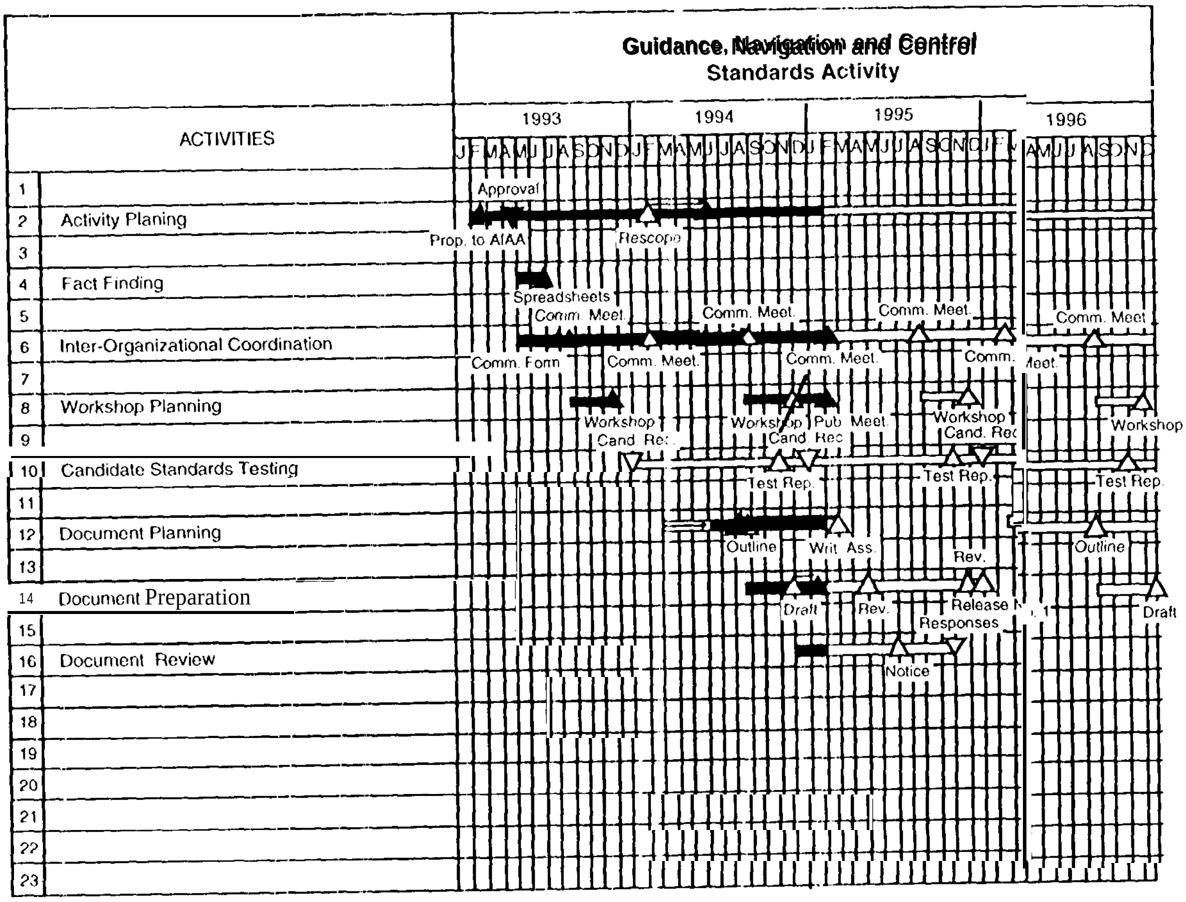

Exhibit 4. Program schedule

Exhibit 5. Overall Scope and Current Focus

Interfaces Between Major Hardware Elements:
Information (Data And Signal; Architecture, Physannel, Connectors, Signaling, Protocols, Dictionaries)
Electrical (Power)
Mechanical
Thermal
Environmental

Software Interfaces:
Between GN&C Applications (Data Passing)
Between GN&C Applications And Operating Systems (Timing And Sequencing)
Between GN&C Applications And Hardware Drivers
Between Hardware Drivers And Hardware

Interfaces Between GN&C Subsystem And Other Subsystems:
Command And Data
Power
Ground Operations Resources

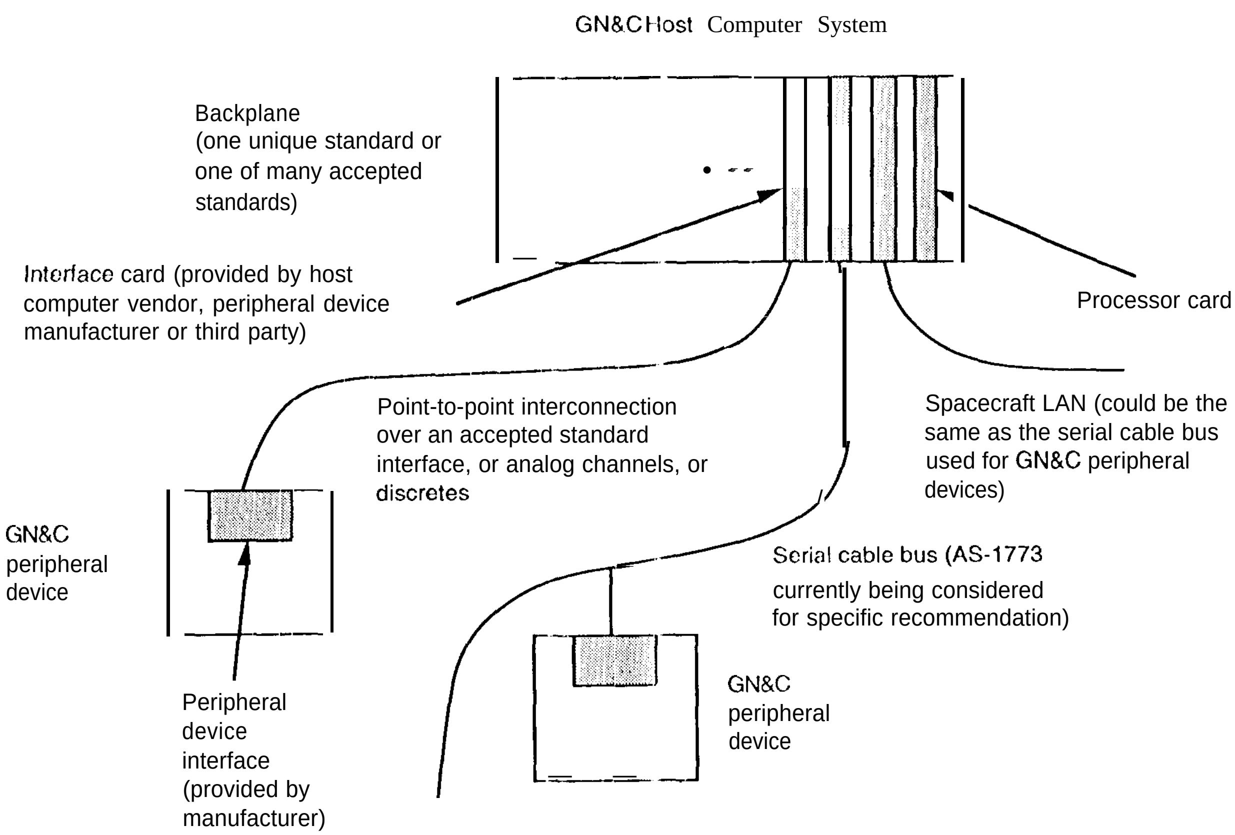

Exhibit 6. Architectural Framework

Exhibit 7. Survey of Information interface.s for Gimbals

OVERVIEW

Gimbals for aerospace and space applications come with a wide variety of electrical interfaces, reflecting the. many possible gimbal designs and spacecraft system designs. A representative sample of gimbal designs are provided, with a summary table that supplies information about the interfaces Used.

The variation in gimbal designs is often the result of the specialized nature of each **gimbal,** as well as the lack of a standard for spacecraft subsystems electrical interfaces. Although the gimbal designs will probably continue to be specialized, the electrical interfaces could be designed to use a standard interface, even if the number and types of parameters passed across that interface were not standard. Many gimbal designs in the past used analog interfaces, and this often made sense for simpler spacecraft. Now that spacecraft arc almost universally operated using imbedded computer systems a digital bus interface becomes the obvious choice.

in gimbal applications, the gimbal requirements will no(drive the choice of an interface, except in the case of high bandwidth applications such as fast steering mirrors. Bus interfaces such as 1553, 422, or 1773 should often be adequate, since most space flight applications will require data rates of less than 100 Hz. The 1 773 bus interface does have the advantage of isolation and lower power. Other sensors, such as gyros and optical sensors, will probably drive the system requirements for bandwidth.

SPACE QUALIFIED GIMBAL INTERFACES - A SAMPLING

The following table provides information on four representative gimbals that have space flight experience or have been qualified for space. They illustrate variety of gimbal designs and interface. implementations that exist,

Unit: Galileo Spin **Bearing Assembly (SBA)** and Scan Actuator Subassembly **(SAS)**

The SBA on the Galileo spacecraft de-spins the de-spun platform from the spun section of the spacecraft, stabilizing the platform in inertial space, and articulates about the de-spun position to provide clock pointing (about the spin axis) for the de-spun science platform. The SAS articulates the science platform perpendicular to the spin axis. Brushless d-c motors arc used for control and absolute position encoders (provided by BEI) arc used for motor commutation and position feedback. The SBA and SAS actuators and electronics were designed and built by Sperry Space Systems for Galileo.

Control **Mode:**

The SBA/SAS arc controlled by commanding torque values to the motor, based on encoder position and gyro information (the gyros arc mounted on the SAS science platform.

Interfa cc:

Custom Digital Bus. The SBA/SAS interfaces with the Attitude and Articulation Control Subsystem (AACS) computer on the spun section through rotary transformers and the De-spun Control Electronics (DEUCE), using a custom serial interface bus at a 15 Hz rate. The DEUCE multiplexes the AACS computer to the SBA and SAS redundant units (A & B), as well as other AACS peripherals mounted on the tic-spun platform. The DEUCE sends a 403.2 kHz clock signal and a 20 bit RZ coded data word to the SBA/SAS, and a 20 bit RZ coded data word is simultaneously returned to the DEUCE.

Inputs:

Digital. A 20 bit data word is sent to the SBA/SAS in the following format.

Bit Number:
1-4 DEUCE port address (determines whether SBA, or SAS, and prime or redundant units arc addressed)
5-9 Always "O"
10-20 11 bit 2's complement torque value, LSB first.

outputs:

Digital. A 20 bit data word is sent to (he DEUCE in the following format.

Bit Number:
1-16 11 bit 2's complement encoder position value, LSB first
17-20 DEUCE port address. This is the address that was part of the original data word sent to the. SBA/SAS.

Analog Temperature measurements. Two analog (O-5 volt) temperature measurements arc provided directly to the spacecraft Command and Data Subsystem. These voltage measurements are the result of applying a I ma current to the temperature sensors.

UNIT: MAGELLAN (MGN) SOLAR ARRAY DRIVE (SAD)

The SAD articulates the MGN solar arrays about the their axes (parallel to the spacecraft X axis). Each drive consists of a stepper motor driving a solar array panel through a harmonic drive assembly. Redundant potentiometers are used for position feedback to the AACS computer. Each motor step is equal to .0075 degrees. The knowledge accuracy requirement is +/- 1.0 % of full scale. The range of motion is +/- 175 degrees and the maximum rate is 1.879 degrees/scc. The SAD actuator anti its associated Electronic Control Unit (ECU) were designed and built by Schaeffer Magnetics incorporated (SMI) under subcontract to Martin Marietta Aerospace. The AACS computer interface electronics were designed to interface to the ECU.

Control Mode:

Motor steps. The position loop is closed in the AACS computer, which commands the number of motor steps necessary to reach the desired position based on the position knowledge.

Interface:

Custom design. The MGN AACS computer interface was designed to accommodate the SMI ECU. Magellan sends commands at a rate of 1 .875 Hz. Discretes are used to control the motor enable, direction and power hold functions of the motor, and the motor is controlled by clock signal to the ECU, where the number of clock pulses defines the number of motor steps commanded and the frequency of the clock signal defines the motor stepping rate. Magellan uses a stepping rate 252 117..

Inputs:

Discrete Signals. The logic levels for the discrete commands are defined as >8.25 volts = "1", <1.0 volts = "O". The discrete commands are:
Motor Enable "O" will enable motor stepping.
Direction "O" will cause counter-clockwise rotation.
Power Hold "O" will cause power to be applied to the motor winding to increase holding torque.

Motor step command. The motor will step every time the step command logic level transitions from a "I" to a "O". The maximum stepping rate is 252 Hz 'with a duty cycle of 50%.

outputs:

Potentiometer position. This is a -S volt to +5 volt signal. This is converted to a 10 bit digital in the AACS computer interface electronics.

UNIT: OCEAN TOPOGRAPHY EXPERIMENT (TOPEX/POSEID ON) HIGH-GAIN ANTENNA SYSTEM (HGAS)

The HGAS articulates the TOPEX High Gain Antenna (HGA) in two axes through a solid cone of -t/- 110 degrees to allow communication the Tracking and Data Relay Satellite (TDRS). The required control accuracy is 0.71 degrees and the knowledge requirement is 0.3 degrees. The Steering Control Electronics (SCE) unit monitors the difference between the sensed position of the antenna and the commanded position and slews the antenna at a rate of 0.5 degrees/second to correct the position when an error is sensed. Resolve.rs are used for position indication and control. The gimbals are actuate.d by 2-phase 4-pole brushless DC motors. The HGAS has been used on other Multi-Mission-Modular Spacecraft (MMMS) such as SMM and MAPS. HGAS was designed and fabricated by Sperry Space Systems under contract to Fairchild Space Company.

Control Mode:

Position Command. The spacecraft On Board Computer (OBC) commands the desired antenna position.

Interface:

Custom design to interface to the MMMS Remote Interface Unit (RIU). The RIU was used on MMMS spacecraft such as SMM, Landsat 4/5, TOPEX, etc., and accommodates digital, analog, and discrete. commands and telemetry between spacecraft peripherals and the spacecraft OBC. Commands can be sent at a periodic rate of 512 milliseconds.

Inputs:

Digital Signals. The following digital signals are provided from the RIU to the SCE to provide clock references or for the digital commands and telemetry.

1.024 Mhz Clock
Serial Command Clock
Telemetry Clock
Serial Command Data
SCE Serial TLM Data

Digital Commands. There are two serial 16 bit commands used to command the HGAS, clocked to the SCE using a 256 kHz clock from the RIU and enabled by the serial magnitude command enable discrete command. The signal and clock use 5 volt logic (J = 5v, O = Ov). The first command (Word 1) is used repetitively to command the position of each axis, and the second (Word 2) is used to command the gimbal heater modes,

Word 1 bits:
O spare
1 Command Word Select O = Word 1
2-3 spare
4 Command Select 1 = GO
5 Axis Select Y = I
6-14 9 bit position command (14 MSB)
1.5 Sign 0 = +

Word 2 bits:
0 spare
1 Command Word Select 1 = Word 2
2 Gimbal Motor Enable/Disable 1 = Enabled
3 Y Axis Gimbal Motor Heater Override Enable/Disable 1 = Enabled
4 X Axis Gimbal Motor Heater Override Enable/Disable 1 = Enabled
5 spare
6 Y Gimbal Heater Enable/Disable 1 = Enabled
7 X Gimbal Heater Enable/Disable 1 = Enabled
8 Spare
9 Deploy Signal Override
10-15- spare

Discrete Commands. Discrete commands are implemented using two kinds of interfaces. A Type 1 interface is an open collector output which provides a switch closure to ground. The second type of discrete (Type 2) is a +28 volt pulse with a pulse width of 6.5-7.0 msec. The Type 1 discretes are used for the Serial Command Enable, the Serial TLM Data Enables and the X/Y Gimbal Override. The Type 2 command is used for switching latching relays, usually in conjunction with a Type 1 interface for the return line of the relay coil.

Discrete Type 1 commands:
Serial Command Enable A (72.2 µsec pulse width)
Serial Command Enable B (72.2 µsec pulse width)
X Gimbal Override
Y Gimbal Override
Serial TLM Data 1 Enable (47.1 µsec pulse width)

Serial TLM Data 2 Enable (47.1 μsec pulse width)
Serial TLM Data 3 Enable (47.1 μsec pulse width)
Serial TLM Data 4 Enable (47.1 μsec pulse width)

Discrete Type 2 commands:
SCE Power ON
SCE Power OFF
SCE Heater Enable
SCE Heater Disable
SCE Heater Override Enable
SCE Heater Override Disable

Outputs:

Digital Telemetry. The SCE has four serial 8 bit digital words, read out through separate interfaces using a 256 kHz telemetry clock signal from the RIU, enabled by the serial digital data enable discrete command. The signal and clock use 5 volt logic (1 = 5v, O = Ov). Instead of the telemetry providing the digital position, the commanded position is provided in digital form, and the error signal is provided as an analog signal. The four telemetry words are defined below. The redundant side words are not shown.

Word 1 bits:
0-6 Y Position Command Magnitude 7 MSB's
7 Y Position Command Sign

Word 2 Bits:
O-1 spare
2 Y Axis Heater TLM 1 = Enabled
3 Y Axis Override Heater TLM 1 = Enabled
4 X Axis Heater TLM 1 = Enabled
5 X Axis Override Heater TLM 1 = Enabled
6-7 Y Position Command Magnitude 2 LSB's

Word 3 Bits:
0-6 X Position Command Magnitude 7 MSB's
7 Y Position Command Sign

Word 4 Bits:
0-2 spare
3 Motor Enable TLM 1 = Enabled
4-5 spare
6-7 X Position Command Magnitude 2 LSB's

Analog Telemetry. The analog telemetry is provided as a signal which varies from 0-5.12 V. The temperature telemetry is similar, but is energized by a 1 ma current pulse from the RIU. The analog signals are provided below.

SCE Y Position TLM
SCE X Position TLM
SCE Y Position Error TLM
SCE X Position Error TLM
SCE Temperature TLM
Y Axis Gimbal Temperature TLM

X Axis Gimbal Temperature TLM

I\i-level Digital Telemetry. These signals provided status for various functions. A logic I is 3.5-15 v, and a logic O is -1.0- +1 .5 v. The signals are:

SCE Y Gimbal Disable
SCE X Gimbal Disable
SCE Deploy Status
SCE Stowed Status
SCE Gimbals Centered Status
SCE Power ON
SCE Clock Status
SCE Heater TLM
SCE Heater Override "1'1 ,M

[J NIT: **INTEGRATED MIRROR POINTING SYSTEM (IMPS)**

The IMPS articulates a 50 inch flat mirror in two axes with a stability of 5 μrads and an accuracy of 22 μ rads. The space qualified IMPS was developed by Orbital Sciences Corporation under contract to Lockheed Missiles and Space Company for the canceled Shuttle-based SDIO Starlab Program.

Control Mode:

The IMPS can operate in 3 different control modes. In the posit ion mode, the inductosyns are used to drive the gimbal to a commanded position; in the rate mode, the gimbal is driven at a commanded rate using a tachometer as the feedback sensor; and in the gyro mode the IMPS is driven by analog torque commands, using the gimbal mounted rate gyro for a feedback sensor.

Interface:

The IMPS uses a custom interface to the Starlab Fast Servo Processor (FSP). The serial digital interface uses asynchronous NRZ-L coded differential signals (261. S30/33) at a 9600 baud rate for commands and telemetry. The word length is 16 bits, with 1 start bit and 1 stop bit per word, MSB first, in 2's complement format. The digital interface can support 50 commands/second and 60 telemetry sanlplcs/second. An analog -t /- 5 volt interface is used for the torque commands.

Inputs:

Digital Drive and Monitor Request Commands can be either two or seven words per burst. Commands include Control, Mode, and Data commands for operation of the gimbal. Data commands can include position (16 bit resolution) and rate. Analog Drive torque signals (+/- 5 volt) are provided to the IMPS for use in the gyro (torquer) mode.

outputs:

Digital Monitor data. Data is formatted as one., two, three. four or six words per burst. Data can include. mirror gimbal position (16 bit resolution), rates, and status. Data is sent in response to interrupt driven data requests form the FSP.

Exhibit 8. Hardware Elements Covered to Date

- Star Sensors
- Sun Sensors
- Horizon Sensors
- Gyros
- Global Positioning System Receivers
- Magnetometers
- Magnetic Torquers
- Thrusters
- Reaction/Momentum Wheels
- Control Moment Gyros
- Gimbals

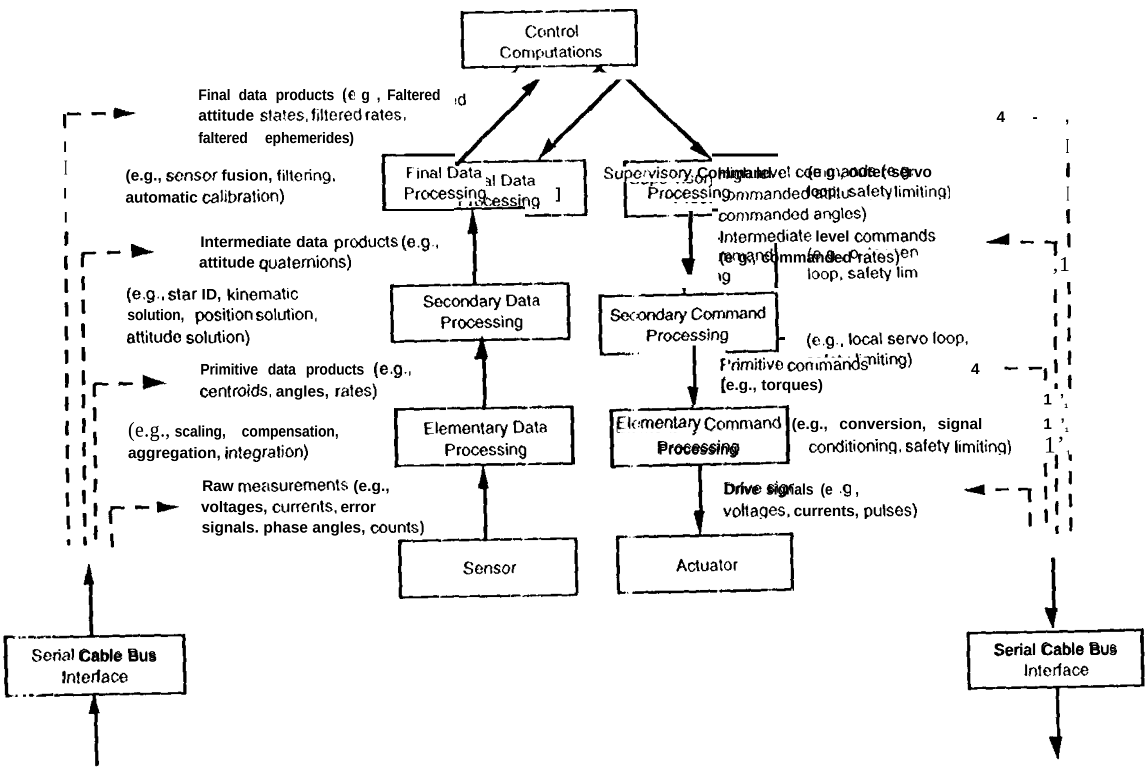

Exhibit 10. Interface Levels

Exhibit 9. Spacecraft Gimbal Strawman information nterface Stand ard, Rev. 2, January 29, 1995

Specific Issues

Several possible command types

- position increment
- position
  speed
- torque
  selectable

Several possible device configurations

integrated encoder
integrated tachometer
integrated torque sensor
integrated tracker
co mbinatio ns of integrated feedback sensors
sensorless

Several possible prime mover types

- torquer
- stepper motor
- positioner

Several possible numbers and types of diagnostic sensors

motor current and temperature for each axis, plus drive electronics temperature for each axis
temperature and motor current for each axis
motor current for each axis
temperature for each axis
none

General Issues

Several timing options (required as a result of the genera time critical nature of control systems)

- fixed rate
  interrogated

Several different synchronization options

synchronous
asynchronous (i. e., free running, time tagged)

commands

Basic device com mands

8 bit 2's complement digital word
- AS-1773 link
includes coded requests for a prime mover command change, including axis
includes coded requests for diagnostic telemetry data (e. g., motor currents and temperatures, and drive electronics temperatures)
includes coded commands to energize heaters, motors, etc.
includes feedback sensor measurement timing mark

Prime **mover command**

32 bit 2's complement digital word
- AS-1773 link
communicated to prime mover within a 10 mscc latency (i. e., interface contributes no more than 10 msec to overall actuator latency)

Measurements

Feedback sensor measurements (where applicable)

up to sixteen 32 bit 2.'s complement digital words
- AS-1773 link
- fixed sensor sequence: encoder, tachometer torque sensor to tracker
- fixed axis sequence: outer to inner for each sensor type
all axes communicated in groups for each sensor type
returned within 10 msec of timing mark (i. e., interface contributes **no more** than 10 mscc to overall sensor latency)

Telemetry sensor measurements

up to nine 32 bit 2's complement digital words
- AS-1773 link
includes measurements of temperatures and motor currents
- fixed sensor sequence: drive electronics temperature, motor current to motor temperature
- fixed axis sequence: outer to inner for each sensor type
all axes communicated in groups for each sensor type
returned within 1 sec of query (i.e. interface contributes no more than 1 scc to overall sensor latency)

Parameters

Configuration data

table of sixteen 8 bit 2's complement digital words
includes coded description of type of prime mover
includes coded description of type of feedback sensor (if any)
includes coded description of control configuration
includes description of number of axes
includes coded description of number and types of diagnostics sensors (if any)
loaded into flight software as data table, as part of device driver, or through self configuring network communications